Knode, Marian

HOEY

From: Knode, Marian
Sent: Friday, May 09, 2003 11:38 AM
To: Hoey, Betsey
Cc: Krynski, William; Tierney, Christine
Subject: Art Unit 1724: Reissue Application 09/866145

Betsey,

This application is not allowable at this time. I am forwarding this reissue to you via your SPE's mailbox for consideration of the following items:

- The maintenance fee has not been paid on the patent (09/055870, US Pat 5906750). The patent issued May 25, 1999. Maintenance fees were due 11/25/02.

Requested DONE (done)

- We need a litigation search for the patent. This can be done by e-mailing STIC-EIC1700. They have a quick turn around time.

- There does not appear to be an assignee in the application. However, if the record is silent as to the existence of an assignee, it will be presumed that an assignee does exist. Applicant must affirmatively state that no assignee exists. See MPEP 1410.01.

- We need to use the copy of the printed patent, in double column format, as the working document. The LIE will need to bleach out the amendments made to the copy of the "original" specification and enter the amendments in the copy of the printed patent.
Additionally any new claims when amended should be completely underlined. See MPEP 1453.

- We will need to cite all references in this application that were filed in the patent. This can be done on an 892.

- Please check the submitted claims for new matter. For example: Claim 13 and 35-36 recites "biological sludge comprises primary sludge" whereas in the patent "biological sludge mixed with primary sludge" (support column 5, lines 1-2). I don't see support for biological sludge comprising primary sludge. Also check claim 17; I don't find support for "wherein step(b) occurs after or simultaneously with step (a)". I may be missing it ......but it's better to be safe than sorry.

- The patent has not been surrendered. This must occur prior to allowing the application.

- Please review the rejections made in Chester's case -- we need to be consistent. The art looks good. Also note claims 17, 18, etc. which do not require the polymeric quaternary ammonium compound.

Please review and return to me in 8B04. Don't hesitate to contact me if you have any questions.

Thanks,
Marian Knode
Acting SPRE
308-4311

(12) UK Patent Application (19) GB (11) 2 284 413 (13) A

(43) Date of A Publication 07.06.1995

(21) Application No 9324916.7

(22) Date of Filing 04.12.1993

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(51) INT CL^6
C02F 11/04 3/30

(52) UK CL (Edition N)
C1C CSBA CSBB C311 C320 C43Y C431 C432 C434 C436 C499 C70Y C702

(56) Documents Cited
WO 93/04988 A1

(58) Field of Search
UK CL (Edition N) C1C CRBA CRBB CSBA CSBB CTBA CTBB
INT CL^6 C02F 3/30 11/02 11/04
Online database: WPI

(54) **Sludge biocombustion**

(57) A sludge biocombustion system comprising a thermophilic aerobic first digester connected in a closed loop to a mesophilic anaerobic digester. Sludge is delivered to the first digester from a settling tank and partially digested sludge is passed from the first digester to the second digester. Partially digested sludge is then returned from the second digester to the first, the partially digested sludge being thickened to maintain the carbon content of the first digester sufficiently high to sustain autothermic operation. Inorganic material is removed from the system. The two digesters are operated so as to maintain a mixed continuous culture.

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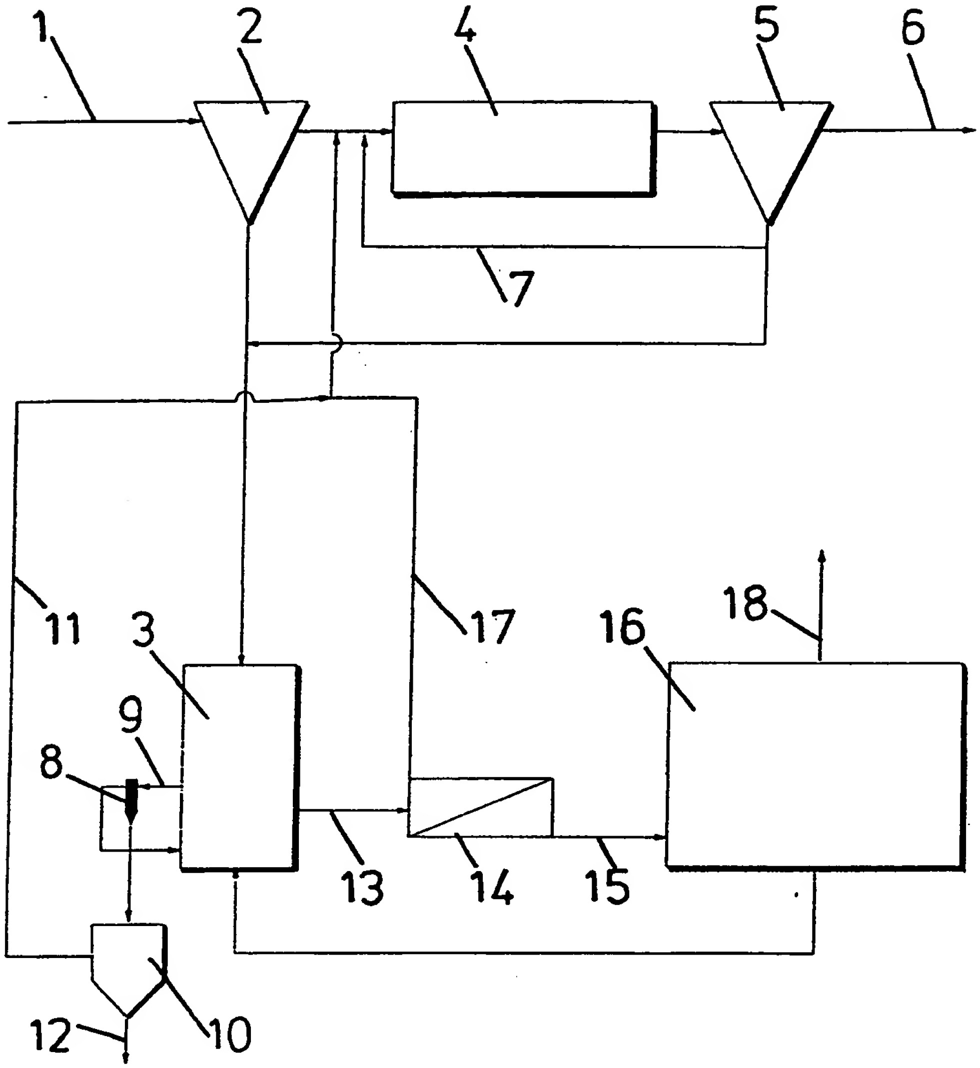

FIG.1

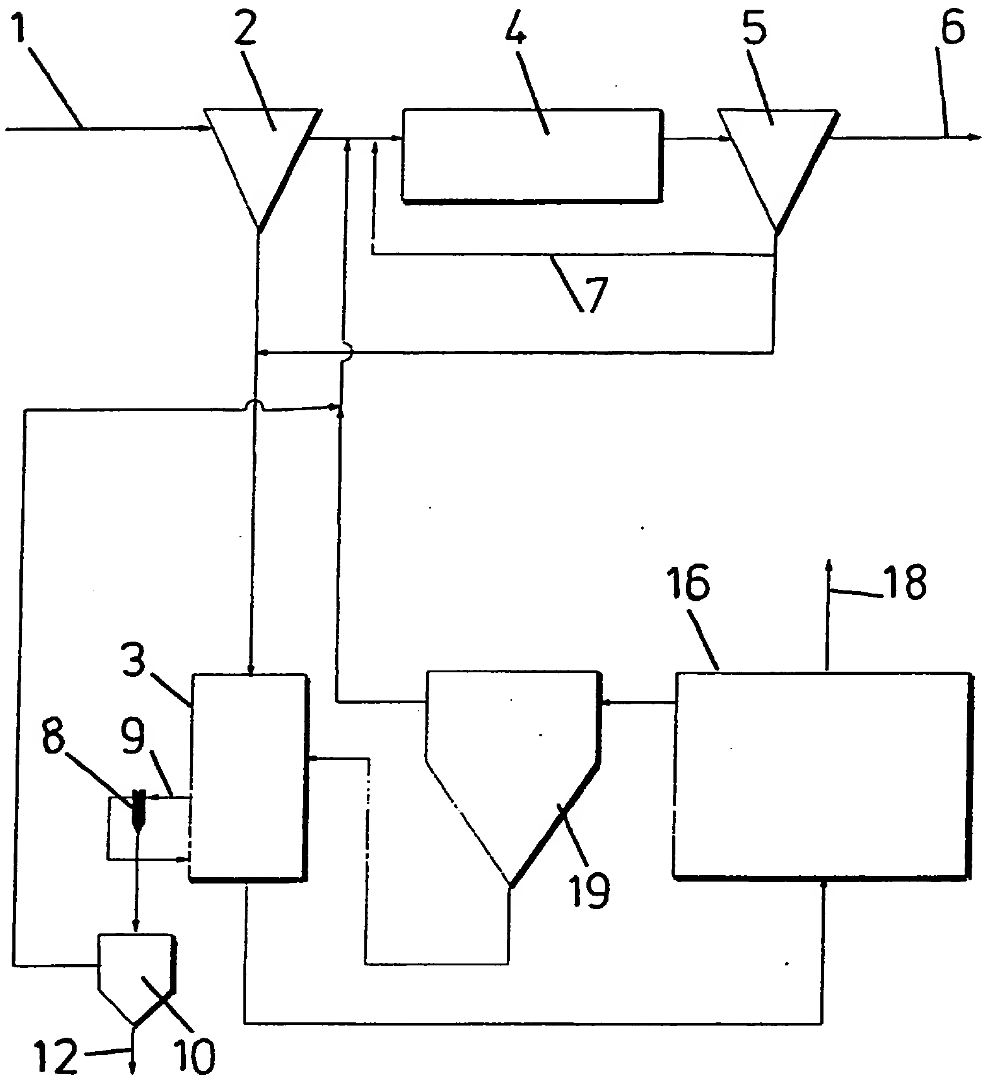

FIG. 2

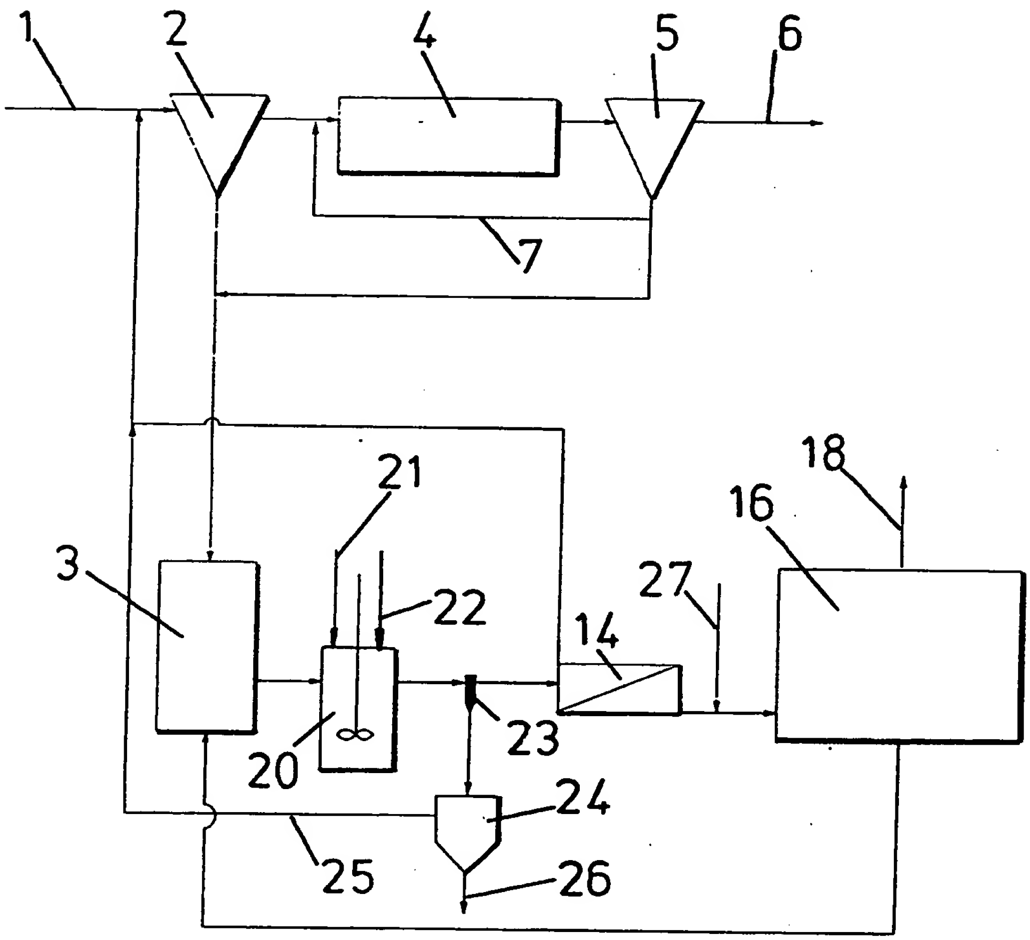

FIG. 3

SLUDGE BIOCOMBUSTION

The present invention relates to a process and apparatus for the biocombustion of sludge.

The water treatment industry processes large volumes of wastewater in the form of domestic sewage, domestic sewage mixed with industrial wastewater, and industrial wastewater. Conventional treatment processes result in the production of large volumes of sludge which must be disposed of, and accordingly there is a need for a wastewater treatment process which greatly reduces the amount of sludge that has to be disposed of and which can be built and operated economically at small and medium sized sites.

It is known to use various biological sludge treatment techniques to convert the organic matter in sludge to gaseous products. These known techniques utilise combinations of thermophilic, mesophilic, anaerobic and aerobic treatments. No operational system has yet been developed, however, which can destroy substantially all of the organic component of sludge so as to leave an inorganic, pathogen-free slurry of relatively small volume for disposal.

Mesophilic anaerobic digestion has found widespread application in the water treatment industry. Broadly speaking the process can be divided into three phases, that is hydrolysis/liquefaction of the particulate organic matter to higher organic acids, acetogenesis of the products of hydrolysis/liquefaction to form acetic acid and hydrogen, and methanogenesis of acetic acid to form methane. Typically these three stages occur concurrently in a broth made up of the sludge and organisms. For the process to achieve maximum reduction in the organic solids fraction, all three stages must be working under near-optimum conditions. Proposals have been made to separate the hydrolysis/acetogenesis stage from the methanogenesis stage to allow optimisation of each stage of the process. Unfortunately this approach does not work as the hydrogen formed during the acetogenesis stage is toxic to many of the organisms required for the hydrolysis stage. When all three stages of the process occur simultaneously in a broth the hydrogen content is regulated by the methenogenic organisms which use it as an energy source.

A major problem with anaerobic digestion processes is the

production of a liquor with a very high concentration of ammonia. The liquors have to be treated either in a dedicated plant or within the wastewater treatment plant by dilution with the main wastewater flow. The production of liquors is unavoidable as ammonia undergoes only limited biodegradation in an anaerobic system.

Heat treatment of sludges in thermophilic biological reactors has been shown to have a number of process advantages. For example, the destruction of pathogenic organisms at higher temperatures allows shorter retention times prior to disposal to agricultural land. Furthermore, sludge is easier to digest after heat treatment, and thermophilic digestion appears to improve the de-watering characteristics of a sludge.

Thermophilic organisms occur naturally in sludge and these organisms can be grown by simply heating the sludge to 65° and aerating. Laboratory experiments on thermophilic reactions indicate that thermophiles preferentially use a particulate substrate. Consequently thermophilic aerobic digestion can be used to advantage in conjunction with mesophilic systems which utilise soluble substrates. Thermophilic aerobic digestion works by using a high intensity aerator (using air or oxygen enriched air) to aerate the sludge. The oxidation process generates heat and the temperature rises. The process may be autothermic, releasing up to 12 kWh of biochemical energy for every kWh of electrical energy consumed. Accordingly this process has found widespread application at small sites.

Clearly there are benefits to both thermophilic and mesophilic digestion, and there are indications that they can complement each other when dealing with a complex substrate like organic sludge. This has led a number of researchers to combine the two processes to form dual digestion systems. One commercially available system has an aerobic thermophilic first stage with a retention time of from 18 to 24 hours followed by an anaerobic mesophilic second stage with a retention time of 8 to 10 days. Such a system is described in the publication "Metcalf and Eddy Inc. 1991, Waste Water Engineering, Treatment, Disposal, Re-Use, 3rd Edition, Published by McGraw-Hill Inc.". Dual digestion systems have the benefit of pasteurising the sludge and solubilising particulate organic matter in the first stage

and the generation of increased volumes of gas in the second stage.

An alternative form of dual digestion has been implemented for treating the sludge from New York. Details are published in Carrio L.A., Lopez A.R., Krasnoff P.J. and Donnellon, (1985), "Sludge Reduction by In-Plant Process Modification: New York City's Experiences", Jour. Wat. Pollut. Cont. Fed., 57, 2, 116-121. The system used in New York relies upon a mesophilic first stage followed by an anaerobic thermophilic second stage. A portion of the sludge from the second stage is then returned to the aeration plant for further aerobic digestion. This process was reported to achieve a reduction in sludge quantity and volume at 47% and 50% respectively. As a result the United States Environmental Protection Agency funded a four year full evaluation of the process, the results of which were published in USEPA, (1990), "Effect of Recycling Thermophilic Sludge on the Activated Sludge Process", Report Reference: EPA/600/2-90/037. The USEPA study was carried out with the use of a control and with rigorous chemical and biological monitoring of each stage of the process. The results of this study contradicted the work carried out in New York, and showed that there was no reduction in sludge quantity.

A multi-stage digestion system has been proposed which it is claimed will result in almost total destruction of organic sludge. That system is described in International Patent Application No. WO93/04988. This document describes a cyclical process for degrading waste organic matter to gaseous products and substantially zero volume of solid matter by subjecting the waste alternately and cyclically to stages of mesophilic and thermophilic digestion in which the organisms from one stage are inactivated and become a substrate for the organisms in the next stage. Inactivation results from the temperature shift between the mesophilic and thermophilic stages. Solids remaining at the end of the cycle are collected and returned to the first microbiodigestion stage for recycling together with a fresh input of waste. In all of the numerous embodiments of the system described, fresh inoculum must be added at the beginning of each digestion stage in order to reseed the process. Reseeding is necessary as the active biomass produced in the thermophilic stage cannot survive under mesophilic conditions.

Patent Specification WO93/04988 describes two examples to illustrate the proposed cyclical system, one having two stages and one having four stages. The two stage system comprises a first mesophilic plug flow stage and a second thermophilic plug flow stage. The four stage system, which appears only to have been implemented in a laboratory by using 250 ml flasks for the fermenter vessels, comprised first and third thermophilic aerobic stages and second and fourth mesophilic aerobic stages. It appears that the two stage proposal is essentially the same process as that which was found not to work in the above mentioned USEPA survey.

U.S. Patent Specification No. 4582607 describes another known waste water treatment system in which partially digested wastewater is circulated between an aerobic thermophilic digester and an aerobic mesophilic digester, but the system is claimed to produce an activated sludge with good sedimentation, rather than converting substantially all of the organic material to gaseous degradation products.

It is an object of the present invention to provide a sludge biocombustion process which obviates or mitigates the problems outlined above.

According to the present invention, there is provided a sludge biocombustion system, comprising a thermophilic aerobic first digester, means for delivering sludge to the first digester, means for passing partially digested sludge including a substantial mesophilic micro-organism population from the first digester to a mesophilic anaerobic second digester, means for passing partially digested sludge including a substantial thermophilic micro-organism population from the second digester to the first digester, means for thickening the partially digested sludge to maintain the carbon content of the first digester sufficiently high to sustain autothermic operation, and means for removing inorganic material from the system.

Thus, the present invention differs from the system described in International Patent Specification WO93/04988 in that it is a two stage system with the first stage being a thermophilic aerobic digester and the second stage being a mesophilic anaerobic digester, and in that the output from each of the stages is only partially digested, obviating the need for the injection of an inoculum. Furthermore, by ensuring the thickening of the material fed back to the thermophilic

digester, autothermic operation is ensured. The system in accordance with the present invention differs from that described in U.S. Patent 4582607 in that the mesophilic digester is anaerobic rather than aerobic. The result of these differences is that the process in accordance with the present invention enables the biocombustion of substantially all of the sludge entering into the system, the processes being applicable in the field rather than in the laboratory.

The present invention also provides a method for reducing the volume of sludge by biocombustion, wherein sludge is delivered to a first thermophilic aerobic digester, partially digested sludge including a substantial mesophilic micro-organism population is passed from the first digester to a second mesophilic anaerobic digester, partially digested sludge including a substantial thermophilic micro-organism population is passed from the second digester to the first, the partially digested sludge is thickened to maintain the carbon content of the first digester sufficiently high to sustain autothermic operation, and inorganic material is removed from the system.

Preferably, the digesters are operated so as to maintain mixed continuous cultures.

The means for removing inorganic material may comprise a degritter through which the contents of the first digester is pumped. The pump may be a venturi aerator arranged in a closed pumping loop connected to the first digester, the degritter being connected in the closed loop. Any convenient alternative aerator could be used however, for example a jet aerator or a pure oxygen system. Furthermore, alternative degritter positions are possible. For example, the degritter may be located downstream of the first digester and upstream of the second digester. The degritter may be a cyclone degritter.

The thickening means may comprise a membrane separator located downstream of the first digester and upstream of the second digester, or a gravity thickener located downstream of the second digester and upstream of the first digester.

Means may be provided for adding acid to the flow of partially digested sludge upstream of the thickening means and for adding alkali to the flow of partially digested sludge downstream of the thickening means. The degritter is preferably located between the

means for adding acid and the thickening means.

The system may comprise an aerator to which a flow of wastewater is delivered, means for separating sludge from the wastewater flow, means for delivering the separated sludge to the first digester, and means for passing liquor separated from the partially digested sludge by the thickening means to the aerator.

Embodiments of the present invention will now be described, by way of example, with reference to the accompanying drawings, in which:-

Fig. 1 is a schematic representation of a first embodiment of the present invention;

Fig. 2 is a schematic representation of a second embodiment of the present invention; and

Fig. 3 is a schematic representation of third embodiment of the present invention.

Referring to Fig. 1, a flow of raw wastewater indicated by arrow 1 is delivered to a primary settling tank 2. The resultant sludge is passed to an aerobic thermophilic digester 3, and the liquid from which the sludge has been separated in the tank 2 is passed to a biological reactor in the form of a conventional aeration basin 4. The output of the aeration basin 4 is passed to a final settling tank 5 from which the final effluent of the plant is delivered as a flow indicated by arrow 6. Sludge separated out in the final settling tank 5 is delivered to the sludge flow passed to the digester 3, liquor produced in the final settling tank being returned to the input of the aeration basin 4 along the path indicated by line 7.

The digester 3 is aerated using a venturi aerator (not shown) with a grit removal cyclone 8 connected in the aerator pumped loop 9. The grit from the cyclone is passed to a gravity settling tank 10, the supernatant liquor being returned to the biological stage of the treatment plant along the path indicated by line 11. Inorganic solids are removed from the settling tank 10 as indicated by arrow 12 for disposal.

The thermophilic aerobic digester 3 is operated so as to maintain a mixed continuous culture such that the output of the digester 3 is only partially digested and includes mesophilic micro-organisms which have not been inactivated. The output of the digester 3 is passed as

indicated by line 13 to a membrane separator 14. The membrane separator 14 thickens the partially digested sludge that it receives from the digester 3, the thickened sludge being passed as indicated by line 15 to an anaerobic mesophilic digester 16, and liquors being returned as indicated by line 17 to the biological stage of the treatment plant.

The anaerobic mesophilic digester 16 is operated so as to maintain a mixed continuous culture, gas generated as a result of the biological processes within the digester 16 being removed as indicated by arrow 18. Partially digested sludge including active thermophilic micro-organisms is then returned from the digester 16 to the digester 3.

Thus the only outputs from the system are the stable, pathogen free inert material removed from the settling tank 10, gas from the digesters, and the final effluent of the treatment plant which flows from the final settling tank 5. Because neither of the digesters inactivates all of the micro-organisms required by the other digester, the system can be operated in steady state conditions which are relatively easy to sustain. It is essential for the process to work, however, that sufficient liquor is removed from the circulating partially digested sludge to ensure that the carbon content of the digester 3 is high enough to sustain autothermic operation. It would not be possible to sustain autothermic operation if, for example, alternate thermophilic and mesophilic digesters were arranged in a serial array of four digesters, two of each type.

Referring to Fig. 2, an embodiment of the invention similar to that of Fig. 1 will now be described. The systems of Fig. 1 and Fig. 2 are very similar and accordingly the same reference numerals are used where appropriate. The only substantial difference between the arrangements of Figs. 1 and 2 is the replacement of the membrane separator 14 of Fig. 1 by the gravity thickener 19 of Fig. 2. Membrane separators have not been widely used in the past in water treatment plants and accordingly it may be preferred to use a gravity thickener such as that shown in Fig. 2 so that all the components of the system are entirely conventional, the operation of such components being well known. In the arrangement of Fig. 2, the partially digested output of the thermophilic aerobic digester 3 is delivered directly to the

anaerobic mesophilic digester 16. Thickened partially digested sludge is then passed from the thickener 19 to the thermophilic aerobic digester 3, liquor being returned from the thickener to the biological stage of the treatment plant. The gravity thickener 19 is used downstream of the anaerobic digester because the sludge from the aerobic stage would be almost totally deflocculated and would not therefore settle readily.

The systems described with reference to Figs. 1 and 2 both rely on the assumption that the biological portion of the sludge is used as a substrate for the following stage, that is aerobic organisms are consumed in the anaerobic phase and vice versa, and that the recalcitrant portion of the solids is "softened" in the thermophilic stage so as to become biodegradable. Depending on the nature of the sludge this may not be the case, and if it is not it would be appropriate to use a more vigorous hydrolysing stage such as that used in the conventional thermic sludge treatment process. In addition, there is the possible problem that materials such as heavy metals would build up in the system. Consequently it may be beneficial to use acid as an aid to hydrolysis in a system such as that illustrated in Fig. 3.

The reference numerals in Fig. 3 correspond to those used in Fig. 1 where appropriate. Sludge is delivered to the thermophilic aerobic digester 3 and partially digested, the resultant partially digested sludge being passed to a tank 20 which is agitated and into which acid is injected as indicated schematically by arrow 21. The acidified partially digested sludge may be heated by the addition of energy indicated by line 22, that energy being derived, for example, by burning gas produced by the anaerobic digester 16. The heated and acidified partially digested sludge is then passed through a cyclone 23 to the membrane separator 14. Organic solids are settled out in a settling tank 24, liquor being returned to the treatment plant via a path indicated by line 25 and the final inorganic solids being removed by a path indicated by line 26.

Downstream of the membrane separator, the acidity would be re-adjusted by injection of alkali as indicated by arrow 27 and delivered to the anaerobic mesophilic digester 16. The partially digested content of the digester 16 would then be returned directly to the

thermophilic aerobic digester 3. If the plant operates with chemical addition to the primary settling tanks the liquor returned from the membrane separator would carry with it the precipitant which would thus be effectively recycled.

CLAIMS

1. A sludge biocombustion system, comprising a thermophilic aerobic first digester, means for delivering sludge to the first digester, means for passing partially digested sludge including a substantial mesophilic micro-organism population from the first digester to a mesophilic anaerobic second digester, means for passing partially digested sludge including a substantial thermophilic micro-organism population from the second digester to the first digester, means for thickening the partially digested sludge to maintain the carbon content of the first digester sufficiently high to sustain autothermic operation, and means for removing inorganic material from the system.

2. A sludge biocombustion system according to claim 1, wherein the first digester is operated so as to maintain a mixed continuous culture.

3. A sludge biocombustion system according to claim 1 or 2, wherein the second digester is operated so as to maintain a mixed continuous culture.

4. A sludge biocombustion system according to any preceding claim, wherein the means for removing inorganic material comprises a degritter and means for pumping the contents of the first digester through the degritter.

5. A sludge biocombustion system according to claim 4, wherein the pumping means comprises an aerator arranged in a closed pumping loop connected to the first digester, the degritter being connected in the closed loop.

6. A sludge biocombustion system according to any one of claims 1 to 3, wherein the means for removing inorganic material comprises a degritter located downstream of the first digester and upstream of the second digester.

7. A sludge biocombustion system according to any preceding claim, wherein the means for removing inorganic material comprises a cyclone degritter.

8. A sludge biocombustion system according to any preceding claim, wherein the thickening means comprises a membrane separator located downstream of the first digester and upstream of the second

digester.

9. A sludge biocombustion system according to any one of claims 1 to 7, wherein the thickening means comprises a gravity thickener located downstream of the second digester and upstream of the first digester.

10. A sludge biocombustion system according to any preceding claim, comprising means for adding acid to the flow of partially digested sludge upstream of the thickening means and means for adding alkali to the flow of partially digested sludge downstream of the thickening means.

11. A sludge biocombustion system according to claim 10, as dependent on claim 1, 2, 3, 6 or 7, wherein the means for removing inorganic material is located between the means for adding acid and the thickening means.

12. A sludge biocombustion system according to any preceding claim, comprising an aerator to which a flow of wastewater is delivered, means for separating sludge from the wastewater flow, means for delivering the separated sludge to the first digester, and means for passing liquor separated from the partially digested sludge by the thickening means to the aerator.

13. A method for reducing the volume of sludge by biocombustion, wherein sludge is delivered to a first thermophilic aerobic digester, partially digested sludge, including a substantial mesophilic micro-organism population, is passed from the first digester to a second mesophilic anaerobic digester, partially digested sludge, including a substantial thermophilic micro-organism population, is passed from the second digester to the first, the partially digested sludge is thickened to maintain the carbon content of the first digester sufficiently high to sustain autothermic operation, and inorganic material is removed from the system.

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Patents Act 1977 Examiner's report to the Comptroller under Section 17 The Search report)	Application number GB 9324916.7
Relevant Technical Fields (i) UK Cl (Ed.N) C1C (CRBA, CRBB, CSBA, CSBB, CTBA, CTBB) (ii) Int Cl (Ed.6) C02F 11/02, 11/04, 3/30	Search Examiner MR R HONEYWOOD Date of completion of Search 7 FEBRUARY 1995
Databases (see below) (i) UK Patent Office collections of GB, EP, WO and US patent specifications. (ii) ONLINE DATABASE: WPI	Documents considered relevant following a search in respect of Claims :- 1-13

Categories of documents

X: Document indicating lack of novelty or of inventive step.

Y: Document indicating lack of inventive step if combined with one or more other documents of the same category.

A: Document indicating technological background and/or state of the art.

P: Document published on or after the declared priority date but before the filing date of the present application.

E: Patent document published on or after, but with priority date earlier than, the filing date of the present application.

&: Member of the same patent family; corresponding document.

Category	Identity of document and relevant passages	Relevant to claim(s)
X	WO 93/04988 A1 (PIRTFERM LIMITED)	1 and 13 at least

Databases:The UK Patent Office database comprises classified collections of GB, EP, WO and US patent specifications as outlined periodically in the Official Journal (Patents). The on-line databases considered for search are also listed periodically in the Official Journal (Patents).